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AGRICULTURAL RESEARCH INSTITUTES AND THE FUTURE *

THE organization and administration of agricultural research, in common with many other national activities, will receive critical—and, it may be hoped, constructive attention as a result of the War. Although the post-war structure of our agriculture cannot yet be predicted with confidence, considerable changes will probably occur, which should be accompanied—and so far as possible, anticipated—by appropriate new perspectives in the agricultural research, advisory and teaching organizations.

We shall here deal primarily with research and further restrict ourselves to arable agriculture. Although other branches, such as animal husbandry and economics, also have their own vital problems, it is not likely that their frame work of organization and administration will need to be vastly different from that proper to research in arable agriculture. Indeed, there are so many problems requiring joint examination that some organization to serve those needs that are common to all branches is not only desirable, but also essential.

If one looks back at, say, the last hundred years of research in arable agriculture, a clear pattern can be seen, especially in Great Britain. There have been two well-defined stages, the second of which is already changing into a third. The picture is one of orderly and progressive development, and the third stage is a logical outcome of the second.

It so happens that the history of Rothamsted well illustrates the sequence. The first stage—the era of Lawes and Gilbert—was a frontal attack on a problem of practical agriculture: the manuring of crops. The method was one of simple and direct field experiments; the function of the laboratories was to produce a mass of expository analytical data on the soils and crops. It is true that valuable novelties were employed in the method of approach: the problem was detached from its context of crop rotations and agricultural systems by growing each crop continuously. The method well served its purpose for it was quick, and it not only gave striking new information on crop nutrition but the field

* Article by Dr. B. A. Keen, F.R.S., reprinted from *Nature*, Vol. 150, No. 3801, p. 282.

results were capable of immediate application to practice. The effects of artificial manures on crop yields were so large that they were not wholly obscured even by widely different soils, climates, and agricultural systems. Lawes and Gilbert took little or no direct part in the repetition of their experiments in other areas. Examination of the increasing mass of the Rothamsted data occupied the greater part of their attention; for very many years Gilbert was absorbed in the nitrogen balance sheet for the various plots and in the amounts of nitrogen that could not be accounted for when the analyses of soil, manure, crop, rain and drainage were put together. Had the study of soil microbiology been as well forward then as agricultural chemistry some of the puzzles would have been clearer. However, the important point was that the conclusions and their technical corollaries might have only a local validity; but the full realization of this was to come only later. The effort, in fact, was somewhat like an attempt to make a synoptic chart for our variable continental-seaboard weather from very detailed meteorological observations taken at a single station.

With the deaths of Lawes and Gilbert the first stage of agricultural research closed. The Rothamsted work had shown that agricultural science had extended beyond the scope of any one man. The need for the help of a microbiologist in a problem that began in chemistry has already been mentioned; and, while biochemistry could advance the frontier of agricultural chemistry, it was, in turn, handicapped by lack of knowledge of the physical environment in the soil. Clearly, the help of research workers in many branches of science was needed if soil and plant relationships were to be further elucidated. This second stage of agricultural research began with modest resources, but the Development Commission, and especially the War of 1914-18, gave it a great impetus. It has now been running for some twenty years in substantially the form planned by its designer, the late Sir Daniel Hall. Weaknesses and merits have had time to show themselves, so a review of the organization is appropriate, the more so in view of the many war and post-war agricultural problems.

It is unnecessary here to set out the achievements of the second phase of agricultural research. To any unbiassed observer they must amply justify the faith of Hall's vision, for the boundaries of agricultural science have been greatly enlarged. To take only one section, a comparison of the original 1912 edition of Russell's "Soil Conditions and Plant Growth" with the seventh, of 1937, shows in striking fashion how far we have travelled in twenty-five years and how much British agricultural scientists have contributed to that progress. The annual reports and papers published by other research institutes—those dealing with market gardening and fruit growing, for example—show equally striking advances in their own spheres of work.

It is important to study the organization under which this work was done. There were some obvious difficulties to overcome: specialists tend to work in water-tight compartments, and few of the new men were likely to have any agricultural background. Thus there was the double problem of fostering team-work so that the new agricultural science should be a coherent whole, and of providing a suitable environment to ensure that technical applications of the scientific advances would not be missed or ignored by the research workers.

Superficially, one single large research institute for the whole of agricultural science would have seemed the solution, but for two inescapable facts: first, agricultural research embraces such widely different activities as animal nutrition, farm economics, plant genetics, and soil physics; and second, effective central direction of research, whether by a director or a committee, is impossible if the number of workers exceeds a certain limited figure. The alternative adopted was a number of smaller institutes, each of which took an agreed broad section of agricultural research as its main concern. A possible looseness of contact between these sections was less important than the reasonable certainty that within each section team-work would build up a coherent picture. Another far-seeing provision was to give each institute the widest freedom of control over its own research programme, for the reason that decentralized control works best. In the past twenty-five years many members of the institutes have studied the organization of agricultural research in other countries, and many overseas visitors have examined our scheme; the almost universal opinion is that none is better than ours and most are less effective.

Nevertheless, no one, least of all those in the research institutes, would claim that the present organization should be continued unchanged merely because it has been successful in the past. Should they be consulted about their own future—and it is to be hoped that they yet will be—it would assuredly be found that those concerned with arable agriculture are anxious that the third stage of agricultural research should be organized, for its pattern and requirements are already quite clear.

The very advances of the second stage showed that many technical conclusions obtained for one soil, climate and agricultural condition were either invalid, or needed modification, elsewhere. To meet this difficulty some of the institutes had built up chains of experimnts as best they could. The problems investigated were necessarily restricted, as only the simplest field procedure could be used. Their scope was further limited because the problems had to be those of immediate interest to official or private organizations able to meet some of the costs and to help in securing sites. Although the experiments were simple, incomplete, and beset by various difficulties, they were amply justified by their results both in agricultural science and practice.

The overriding needs of war-time agriculture have removed, for the time at least, some of the difficulties: contacts with other institutes and advisory officers are increasing, and an informal network of co-operative field experiments (and demonstrations) is developing. For the first time there emerges a possibility of joint work on some important agricultural problems not included within the interests of official and private organizations.

The freedom of development that characterized the second stage of agricultural research has not only produced the third stage as a logical outcome; it has also provided the technical machinery that makes the next stage possible. The statistical design of experiments to secure comparable results of an ascertainable degree of accuracy enables the maximum of information to be obtained from a given amount of experimental effort, by combining several related questions in one design. Thus, problems concerning two or more research institutes could be dealt with in the same experiment. Such a scheme of field experiments would need co-operative control by the interests concerned through a committee which might work under the aegis of the Agricultural Research Council. The committee would be responsible for selecting the programme from the various proposals put forward and for combining the selected problems in the most economical manner. Each experimental site would be typical of an important soil and farming system.

It is certain that a system of well-distributed replicated experiments will be of the utmost value to the research institutes. It is equally certain that it will enable rapid answers to be given to many urgent post-war agricultural problems of a practical and economic nature, for as already stated, it is growing up even now under the compelling pressure of immediate war-time problems.

Wars and their aftermaths are conducive to centralized control of many activities. The majority of research workers regard such controls as temporary necessities which have an unfortunate tendency to persist after the need for them has vanished. Lest it should be thought that the scheme outlined above is merely another fashionable war-time centralization, it is desirable to stress the following points: the need for it was apparent before the War; it is a natural development from a second to a third stage of agricultural research. Finally, it does not call for any significant changes in the control and administration of the research institutes. Their record during the twenty-five years of the second stage of agricultural research, and the fundamental work now in hand projected, are enough to show that they are still efficient instruments in the furtherance of agricultural science.

As stated at the outset, we have dealt here only with the organization and administration of research in arable agriculture. Contacts with colleagues in various other branches lead one to believe that among agricultural research workers there is general agreement on the situation briefly discussed here and on the best method of dealing with it. But agricultural science ranges so widely that workers in other branches will have their own proposals to offer for the general plan of research organization. One purpose of this article is to promote discussion in the belief that a common ground of agreement will emerge; there is no doubt that, especially at the present time, such discussions and expressions of opinion will be very opportune.

TONGUE-INARCHING OF THE AVOCADO

A modification of the ordinary method of inarching or approach grafting is described by J. P. Torres in the *Phillip. J. Agric.* Vol. X, I. In this method, after the outer surfaces of stock and scion are pared as usual, a tongue is cut farther into the wood, behind each of these cut surfaces, as in the whip and tongue graft but of greater length. The tongue on the stock is cut from above downwards and on the scion from below upwards, so that when placed in position the split portions interlock, one behind the other. The tie is made with waxed tape. Advantages claimed over the ordinary method are:— There are three lines of contact instead of one, so that union is quicker and more certain and the date when the plants may be severed is reduced by four weeks or more (the usual time for ordinary inarching with the avocado is from 8-12 weeks), there is a firmer union and a more rapid sap flow and consequently growth; stock and scion need not be of equal width; if, however, the stock is narrower than the scion the part below the union may remain small for some time. Preliminary trials have shown a 99 per cent. take for the improved method of inarching against 66 per cent. for the ordinary method, a maximum of 40 per cent. for marcotting and a maximum of 65 per cent. for budding. Types of avocado that fail to bud owing to the unsuitability of the budwood can be tongue-inarched with ease; the operation can also be done all the year round in wet or dry seasons, and overgrown stocks unsuitable for budding or grafting can be used. It is recommended that instead of pruning off low-hanging branches of choice varieties they should instead be tongue-inarched. A number of other fruits have responded well to the method.

PRELIMINARY STUDIES OF THE PLANT VIRUSES OF TRINIDAD

BY

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I. Introduction and Review of Literature

Although the study of plant virus diseases has made great progress in recent years, there are comparatively few records of these pathogens in Trinidad. Maize leaf stripe (*Zea Virus* 1 K. M. S.) has been described in some detail by Briton-Jones (5), and has been experimentally transmitted to sorghums by means of its leafhopper vector, *Peregrinus maidis* Ashm., but cane mosaic (*Saccharum Virus* 1 K. M. S.) is uncommon in Trinidad, although recorded on both cane and maize. Mosaics of the *Leguminoseae* are more common, and Briant and Martyn (4) and Pickles and Thorold (16) studied a mosaic of cowpeas (*Vigna unguiculata* (Linn.) Walp.). A mosaic of woolly pyrol (*Phaseolus mungo* Linn.) was shown to be due to the same virus, and was mechanically transmitted to *Phaseolus aureus* Roxb. (16). A mosaic of beans (*Phaseolus vulgaris* Linn.) has also been previously noted (2). Virus diseases of the *Solanaceae* also occur commonly, and Baker (2) has reported regular outbreaks of mosaic on tobacco at the College farm in recent years, while outbreaks of mosaic disease of sweet peppers (*Capsicum annuum* Linn.) and of tomatoes have occurred. Topper (24) described disease symptoms of tomatoes thought to be due to a mosaic virus, but he was probably dealing with the disease known as "wet weather disease" (2), a condition which may be due to virus infection or to unknown physiological causes. A mosaic of papaws (*Carica papaya* Linn.) is common in Trinidad (3) but, while similar mosaics in other countries have been shown to be of virus origin, the Trinidad papaw mosaic has not yet been experimentally transmitted. A probable virus disease, causing a mottling of the leaves of cotton, shown to be graft transmissible, has occurred at the Empire Cotton Research Station, and a mosaic, which cannot be transmitted mechanically, occurs commonly on other wild and cultivated members of the *Malvaceae*. Mosaic mottlings have been reported (16) on the following weeds:—*Centrosema* sp.; *Mucuna* sp.; *Triumfetta* sp.; *Sida* spp.; *Alternanthera polygonoides* and *Amaranthus spinosa*. Reference to certain other suspected virus diseases of weeds is made at the end of this paper.

II. Methods

The study of plant virus diseases involves the carrying out of many controlled inoculation experiments, and sap transmissible viruses are consequently much easier to study than those in which specific insect vectors or grafting methods are necessary to effect transmission. Thus, in this investigation, whilst the latter have received some attention, encouraging results have been so far obtained only from the study of mechanically transmissible types.

Insect proof cages were designed, in which it was intended to grow all plants used in inoculation experiments, but these proved to be unsatisfactory and were used in only a few experiments. The majority of the plants were therefore grown in the greenhouse, or in open plots, large numbers of plants being used for each experiment, so that natural insect transmission could be estimated from the number of control plants developing disease symptoms. In practice this procedure has been justified, very few natural infections having taken place in the course of the experiments.

In the mechanical inoculation of plants with sap transmissible viruses, the most generally satisfactory method involves the gentle rubbing of a leaf of the plant it is desired to infect with the expressed sap of diseased plants, and this method has given the best results in the present investigations. The leaves of diseased plants were ground up with a pestle and mortar, together with a little sterile water, the extract then being rubbed gently over the under surface of the leaf with a piece of soft cloth.

III. Cowpea Mosaic Virus

The mosaic of cowpeas (*Vigna unguiculata* (Linn.) Walp.) already recorded in Trinidad (4, 16) spread rapidly in crops on the College farm and certain other areas during 1942. A few infected black-eye cowpeas were transplanted into the experimental plot and a small crop of the "gub-gub" variety was planted nearby. Within a few weeks of germination the latter had become completely infected by the disease. The first sign of infection is a "clearing of the veins" of the youngest leaves, and the next leaflets to expand have an irregular light and dark green mottling, while blistering of the laminae often occurs. The symptoms become less marked with age, especially when the plants are growing rather slowly under unfavourable conditions. The symptoms are variable and very young plants inoculated artificially may develop mottling and blistering of the first trifoliate leaves, there being no "vein clearing" stage. Plants infected when older suffer less check to growth than those developing symptoms earlier and, as with most viruses, symptoms only develop on leaves expanding after infection.

Mosaic was transmitted mechanically from black-eye to "gub-gub" and *vice versa*, and "bodie" beans were also successfully infected from diseased

"gub-gub" plants. The "bodie" or "yard-long" bean belongs to the asparagus bean type of *V. unguiculata* (20) often referred to as *Vigna sesquipedalis* (Linn.) Fruw.

Pickles and Thorold (16) have already shown the mosaic of woolly pyrol (*Phaseolus mungo* Linn.) to be due to the same virus as cowpea mosaic; they also showed that it produces the same type of symptoms on *P. aureus* Roxb. It was less common on woolly pyrol than on cowpeas in 1929, but the woolly pyrol mosaic seems to have been more common then than in 1942, in which year it only appeared naturally on a few plants in a "museum plot" on the Farm and in the experimental virus plot, the plants growing, in each case, near to infected cowpeas. When young woolly pyrol seedlings become infected, the young leaves develop severe yellow and green mottling and blistering. As the plants become older the symptoms become less marked, mature plants showing merely a slight yellowish flecking of the leaves. When young plants are infected there is a serious growth check, but more mature plants are only slightly affected.

Cowpeas were readily infected artificially with mosaic from woolly pyrol, and *P. aureus* and woolly pyrol almost equally easily with mosaic from cowpeas. Faint yellow areas developed on the inoculated leaves of *P. aureus*, prior to the appearance of systemic symptoms.

A few soya beans (*Glycine max* (Linn.) Merr.) on the College farm were found suffering from a marked stunting, due to shortening of the internodes and petioles. The leaves were darker green than normal and rather crinkled, the edges curling downwards. Many axillary shoots proliferated, and the small leaves of such shoots often showed a light and dark green mottling. Plants infected when young produced little or no seed and remained dark green when the rest of the crop was yellowing and ripening off. These symptoms are very similar to those of soya bean mosaic (*Soja Virus* 1 K. M. S.) described from U. S. A. (9) but, as far as is known, that virus has never been transferred to any host other than the soya bean by artificial inoculation. The Trinidad disease, however, was found to give rise to normal cowpea mosaic symptoms, while no difficulty was experienced in transmitting mosaic from cowpeas to soya beans, the latter developing symptoms identical with those of naturally infected plants. Thus, the Trinidad soya bean mosaic does not appear to be caused by *Soja Virus* 1, but by the common cowpea mosaic virus. Very young seedlings were found to be seriously affected when inoculated with the virus, growth practically ceasing and the petioles becoming shortened and twisted and the leaves puckered and darker in colour than those of the control plants. Soya beans inoculated in the greenhouse showed shortening of the petioles and internodes compared with the controls, and under these conditions there appeared quite a pronounced leaf mottling, in addition to the proliferation of axillary shoots.

A few Sunn hemp plants (*Crotalaria juncea* Linn.), on the Farm, were found to be suffering from mosaic symptoms. The leaves were blistered and mottled with light and dark green areas, the plants being very stunted at first but improving as the leaf symptoms became less marked with age. Such plants, at maturity, were smaller than normal, although they set plenty of seed. The mosaic was found to be readily sap transmissible to other Sunn hemp seedlings, and identical symptoms were produced by inoculating Sunn hemp with cowpea mosaic. Furthermore, normal cowpea mosaic symptoms appeared on cowpea and woolly pyrol seedlings inoculated with an extract from naturally infected Sunn hemp, showing that this mosaic was also caused by cowpea mosaic virus.

Lima beans (*Phaseolus lunatus* Linn.) were artificially infected with this virus, although the percentage of successful inoculations was lower (40%). Plants grown from local seed, of the pure white Carolina Lima and black mottled varieties, seemed to be about equally susceptible to the disease. The disease was readily transmitted back to cowpeas, and also to Sunn hemp, from infected Lima beans. The virus has not yet been observed occurring naturally on this host, and all the control plants remained healthy throughout the experiments.

The leaf symptoms produced on Lima beans were similar to those of cowpeas, the leaves of plants infected in the open generally being severely blistered and flecked with yellowish green. Symptoms of this type often appeared under greenhouse conditions, but a milder dark and pale green mottling, with practically no leaf distortion, was sometimes observed. Quite often, both in the open and in the greenhouse, symptoms almost disappeared for a time from the young leaves, only to reappear in a severe form at a later stage. The mosaic of Lima beans in U. S. A., caused by a strain of cucumber mosaic virus (*Cucumis Virus* 1 K.M.S.), produces only primary lesions on cowpeas (var. Black), but the mosaic of cowpeas described from U.S.A. by McLean (15) has been shown to be capable of infecting the Lima bean.

Pigeon pea (*Cajanus cajan* (Linn.) Millsp.) seedlings were infected in the greenhouse with the virus from cowpeas. The plants became stunted and showed "clearing of the veins" of the leaves and in some cases leaf chlorosis and distortion. The disease was readily transmitted back to cowpeas. Pigeon peas have never been seen naturally infected with the disease.

Attempts to produce symptoms on the following plants have so far proved unsuccessful:— *Phaseolus vulgaris* Linn.; *Dolichos lab-lab* Linn.; *Canavalia ensiformis* DC.; *Nicotiana tabacum* Linn.; *Lycopersicon esculentum* Mill. and *Cucumis sativus* Linn. A *Canavalia* plant in the experimental plot was found to be very stunted, whilst its leaves were chlorotic, small and rather misshapen, but attempts to transmit this condition

to either cowpea or *Canavalia* seedlings were unsuccessful. The common weed *Desmodium frutescens* (Jacq.) Schindl. has been observed suffering from very typical mosaic symptoms, but it has not been found possible to transmit the symptoms to cowpeas.

IV. The Transmission of Cowpea Mosaic Virus

Since Reddick and Stewart (19) first reported seed transmission of common bean mosaic (*Phaseolus Virus* 1 K. M. S.), the phenomenon has been reported in the case of other legume viruses, including the mosaic virus of cowpeas which is common in U. S. A. Pickles and Thorold (16) found no evidence of seed transmission of cowpea mosaic virus in Trinidad, either in cowpeas or woolly pyrol. In the present investigation, over eight hundred seedlings of "gub-gub" cowpea, raised from the seed of plants infected when quite young, showed no sign of mosaic, although they were grown until the expansion of the second compound leaf. McLean (15) has shown that seed transmission of the U. S. cowpea mosaic does not occur in all cowpea varieties, and further study of cowpea mosaic virus in Trinidad, with respect to seed transmission, is necessary in view of its importance in the initiation of infection in a crop. Further study of the host range of the virus is also needed in view of the importance of "reservoirs of infection" in the initiation and spread of the disease. That various crop plants can carry the disease has already been shown, and it is possible that some of the numerous wild legumes may do the same.

The rapid spread of the disease in cowpeas suggests the presence of efficient and numerous vectors. The disease has been shown to be very easily sap transmissible (see Table I), and such diseases rarely have a single specific insect vector. The leaf-eating Chrysomelid *Ceratoma ruficornis* Oliv. does considerable damage to cowpeas and has been found, in smaller numbers, on other legumes such as *Phaseolus vulgaris, P. mungo, Glycine max* and *Dolichos lab-lab.* Smith (21) has reported *Ceratoma trifurcata,* a closely related species, to be an efficient vector of the cowpea mosaic common in U.S.A., and a preliminary experiment has suggested that *C. ruficornis* may be a vector of cowpea mosaic in Trinidad.

Pickles and Thorold (16) obtained no statistical difference between the yields of mosaic diseased and healthy cowpeas, but infection by the disease does cause an obvious check to cowpeas infected when very young, and the effect on certain other hosts, such as soya bean, is more serious. Fortunately, except in the case of soya beans growing in a small plot adjacent to heavily infected cowpeas, the proportion of diseased plants was so low that the damage was negligible. Since the disease has been readily transmitted artificially to several Leguminous crops, the low incidence of the disease found naturally on these crops may be due to feeding preferences of the vectors concerned in the spread of the disease.

There seems to be nothing to suggest that the Trinidad mosaic of cowpeas and that described by Elmer (8) are the same and Price's (18) cowpea mottling strain of cucumber mosaic has not been found occurring naturally, and neither do the symptoms it produces resemble those of the disease found here. Snyder's (23) mosaic of *V. sesquipedalis* seems to be more specific in its host range and shows a very high percentage of seed transmission. McLean's (15) photographs of the common mosaic of cowpeas found iu U.S.A indicate that the symptoms of the disease are very similar to those found on cowpeas in this Island. The diseases are also similar in that both have been transmitted to Lima beans, but McLean was unable to produce symptoms on *Phaseolus aureus,* although he reports that the attempt was made under rather adverse conditions. A mosaic

Table I.—Inoculation experiments with cowpea mosaic virus

Source of inoculum	Plants inoculated	Number inoculated	Number infected	Incubation period (days)
cowpea var. gub-gub ...	cowpea var. black-eye ...	8	6	8-11
,, ,, ...	var. bodie	7	7	7- 8
,, ,, ...	*Phaseolus mungo*	33	22	5-13
,, ,, ...	soya bean	16	16	8-14
,, ,, ...	Lima bean	55	22	8-14
,, ,, ...	Sunn hemp	12	12	4- 6
var. black-eye	pigeon pea	10	6	10
,, ,, ...	*Phaseolus aureus*	12	12	8
Sunn hemp	Sunn hemp	26	26	9
,, ,, ...	*P. mungo*	5	3	10
,, ,, ...	cowpea	4	4	5
soya bean	soya bean	30	27	10-12
,, ,, ...	cowpea	10	10	8-10
Lima bean	Sunn hemp	20	17	8
,, ,, ...	cowpea	40	40	5-12
P. mungo	,, ...	10	10	7-10
pigeon pea	,, ...	10	10	6

Note.—All controls remained healthy, except 4 out of 27 soya beans in the open plot, near to which diseased cowpeas were growing.

of cowpeas, again apparently similar to that prevalent here, has been described from India by Vasudeva (25), whilst Yu (26) reports a cowpea mosaic from China. A mosaic of *Phaseolus mungo* occurs in Jamaica (14), and it is possible that this and the cowpea mosaics of McLean and Vasudeva are due to the same virus as the Trinidad cowpea mosaic; the mosaic symptoms of cowpeas in China are not described.

V. Common Bean Mosaic Virus—Phaseolus Virus 1 K. M. S.

The virus of common bean mosaic is widespread in the United States, from whence Trinidad imports some of its bean seed (*Phaseolus vulgaris* Linn.), and, as the virus has been shown to be capable of seed transmission (19), it is not surprising to find it quite common here, producing symptoms similar to those described by workers in U.S.A. On highly susceptible local bush bean varieties, the first sign of infection is a slight chlorosis of the youngest leaves which, on expanding, develop a definite light and dark green mottling. The laminae of later formed leaves often tend to curl downwards at the edges and become rather blistered, such leaves remaining smaller than normal and often becoming faintly mottled. Shortening of the internodes and petioles, and the frequent production of chlorotic axillary shoots give the plant a stunted, bushy appearance. Plants of these varieties, infected when small, or growing from infected seed, remain very stunted and fail to produce seed, but those which become infected when rather older may produce a few pods. Severe symptoms, similar to those described above, are characteristic of the disease when it infects a local bush variety with small black seeds, but this variety can produce a few seeds even when infected early in development, and in some cases when the infection is seed-borne. Later infections appear to have little effect on cropping in this variety. The climbing variety Kentucky Wonder is more tolerant to the disease; a few plants have been seen showing a slight crinkling of the leaves but no mottling symptoms. Pierce (17) has reported the similar behaviour of this variety in the United States.

Most seed samples of bush bean varieties in Trinidad give rise, on germination, to a small percentage of stunted plants with mosaic symptoms, obviously due to very early infection or seed transmission. Seed transmission is said to occur rarely when the parent plant becomes infected after flowering, whilst the percentage is much lower when infection takes place during the growing season than when the plants have been diseased throughout the season. This would account for the failure to demonstrate seed transmission using seed from infected red beans since these plants do not set seed unless they contract the disease at a late stage of development. Larger quantities of seed were obtained from infected plants of the small black-seeded bush variety, and these were germinated in the greenhouse, together with seed from healthy plants as a control. A figure of approximately ten per cent. seed transmission was obtained from these trials (Table II). The figure is lower than that recorded from U.S.A. (30-50%), but some of the plants from which seed was obtained may have become infected rather late in development.

Table II—Seed transmission of common bean mosaic

	Plants germinated	Plants dead*	Healthy plants	Mosaic plants	%seed-borne infection
SEEDLINGS FROM SEED OF MOSAIC INFECTED PLANTS					
Group 1	132	5	113	14	11.0
Group 2	115	9	95	11	10.4
Group 3	133	7	110	16	12.7
Group 4	147	6	131	10	7.1
Total ...	527	27	449	51	10.2
SEEDLINGS FROM SEED OF HEALTHY PLANTS					
Group 1	79	8	71	0	—
Group 2	125	11	114	0	—
Total ...	204	19	185	0	—

*Seedlings dying before it was possible to ascertain whether or not they carried the virus were ignored in calculating percentages.

This disease, unlike cowpea mosaic, has proved very difficult to transmit mechanically, this being a characteristic of *Phaseolus Virus* 1. Various local dwarf types, together with a St. Vincent red dwarf variety have been artificially infected, but repeated attempts, using the cloth rubbing method, have failed to cause infection in more than an average of about one in twelve of the plants inoculated. Plants used in inoculation experiments must be grown from the seed of uninfected plants; otherwise seed transmission may cause misleading results. Symptoms take longer to develop after inoculation than in the case of cowpea mosaic, usually appearing after about three weeks.

Unsuccessful attempts have been made to transmit the disease mechanically to the following plants:—*Phaseolus aureus; P. lunatus; P. mungo; Vigna unguiculata* ("gub-gub" and black-eye); *Dolichos lab-lab* and *Crotalaria juncea*. The disease has been transmitted to various legumes in U.S.A., including *P. aureus* and *P. lunatus*, so that failure to infect those plants here is probably due to the unsuitability of the inoculation technique. Mosaic symptoms on Lima beans (*P. lunatus*), distinct from those produced by the cowpea mosaic virus, are quite common. The leaves are very slightly distorted when young, and later develop a well-marked mosaic pattern with well-defined patches of light green or even yellow. Attempts to transmit this disease mechanically to both *Phaseolus vulgaris* varieties and *P. lunatus* itself were unsuccessful,

although this is not taken as proof that the symptoms were not due to *Phaseolus Virus* 1, in view of the difficulty of transmitting that virus by mechanical means.

Reports from the United States indicate that at least eleven different aphids can transmit the disease (27), but there are no records of its transmission by other insects The disease has often spread rapidly in crops of beans in Trinidad. Further study of the virus is needed in order to ascertain its alternative hosts; if these are numerous or common the control of the disease, other than by the use of resistant varieties, seems practically hopeless. If the alternative hosts are not common, it should be advantageous and feasible, on a garden scale, to select seed from healthy plants, marked before ripening, when it becomes difficult to detect symptoms of the disease. Rogueing out infected plants is probably useless on account of the general rapid spread of infection.

The following are some of the resistant varieties and strains which have been selected in U.S.A. :—Red Mexican—U.I.3 and U.I.34 ; white strains of the variety Great Northern—U.I.81, U.I.59 and U.I.123 ; the Refugee beans U.S.1 and U.S.5, Idaho Refugee, Wisconsin Refugee and Robust. The climbing variety Kentucky Wonder is not seriously affected by the virus, but all tested bush beans in Trinidad are very susceptible.

VI. Tobacco Mosaic Virus—Nicotiana Virus 1 K.M.S.

Tobacco mosaic virus has a wide host range in a number of plant families, and has been recorded from almost every area where tobacco is grown, and also from other areas where it causes a disease of tomatoes known as mild mosaic. Numerous "strains" of the virus have been described, differing in properties from the common "type strain". The latter is characterised by great resistance to heating, drying, dilution and inactivation by chemicals; it is highly infectious and very readily sap transmissible. The symptoms caused by the "type strain" on tobacco are of a mosaic pattern. Primary lesions do not normally occur on the inoculated leaf, and a common early symptom of systemic infection is a clearing of the veins of the youngest leaf, this being followed by a dark and light green mottling and slight distortion and blistering of the lamina (22). The dark green areas often tend to follow the main veins, whilst the lighter areas lie between them. Identical symptoms appeared on a few tobacco plants at the Farm during the past season, but the main crop did not show infection; Baker (2) has reported up to 30 per cent. infection of crops on the College Farm in recent years. There is no doubt that the mosaic found here is due to a typical strain of *Nicotiana Virus* 1, which also causes symptoms on other Solanaceous hosts identical with those reported from elsewhere.

On several occasions during the past year typical mosaic symptoms have developed on varieties of pepper (*Capsicum annuum* Linn.) at the Farm. The first symptom of the disease was a slight light and dark green mottling of the young leaves; these later became, in some cases, almost completely yellow and very crinkled, these severe symptoms being followed by considerable abscission of leaves. The fruits produced by such diseased plants were few, due to the abscission of many flowers and young fruits, and sometimes the disease became acute and resulted in the premature death of plants. Mottling and stunting of *Capsicum annuum* caused by the virus of cucumber mosaic (*Cucumis Virus* 1 K.M.S.) have been reported (7), and a mosaic disease of peppers in U.S.A., and elsewhere, is known to be caused by the virus of tobacco mosaic. A series of experiments has indicated that the latter virus is also responsible for the mosaic in Trinidad. Young sweet peppers (*C. annuum*) of the Windsor A and Improved Ruby King varieties were readily infected with the disease from both tobacco and peppers, the symptoms produced being identical. Primary yellowish spotting of the inoculated leaves developed in about three days, systemic mottling and leaf abscission occurring in from four to twelve days from the date of inoculation. It also proved easy to transmit the virus from infected sweet peppers to healthy tobacco seedlings of the Yellow Mammoth and S.R. 25 varieties, all the inoculated plants developing systemic symptoms in five to fourteen days. When young "Red Hot" pepper seedlings (*C. annuum*) were mechanically infected with virus from tobacco plants, severe leaf abscission was followed by partial recovery, the subsequent faint mottling being confined to the youngest leaves. Small-fruited bird peppers (*C. frutescens* Linn.), common around the College farm, frequently show chlorosis and crinkling of the leaves, but rubbing the juice of these plants on to the leaves of tobacco seedlings produced no symptoms on the latter. Mosaic symptoms of *C. frutescens* in U.S.A. have been induced by *Nicotiana Virus* 1.

Tomato mild mosaic was found naturally on only a few tomatoes (*Lycopersicon esculentum* Mill.) on the Farm, but so mild are the symptoms that it may be more common than observations have suggested. The damage caused by the disease was, however, negligible compared with the effects of "wet weather disease" (2). The symptoms of the latter are in many ways suggestive of a virus infection, but there is as yet no proof of this, and it may be a "physiological" disease, as the tentative name suggests. The first sign of infection with mild mosaic is a slight distortion of the youngest leaflets, which are streaked with pale green and slightly blistered with raised darker green areas. The symptoms become, in general, less marked with age. Sap from tomatoes suffering from mild mosaic, when rubbed on to the leaves of tobacco plants, gave rise to typical symptoms of tobacco mosaic. Similarly, no difficulty was experienced in transmitting the virus from mosaic-infected tobacco and sweet pepper plants to tomatoes, on which the normal symptoms of mild mosaic were produced.

It was found that when the leaves of young egg plant seedlings (*Solanum melongena* Linn.) of the Black Beauty variety were rubbed with a juice extract from tomatoes suffering from mild mosaic numerous primary necrotic spots appeared on the inoculated leaves within three days. These spots increased in size and coalesced, the inoculated leaves finally wilting and being abscissed. No systemic symptoms later developed on any of the plants, and on subsequent re-inoculation of the same plants, identical primary symptoms appeared. No symptoms of any kind appeared on plants inoculated when more than about six weeks old. The behaviour of plants of the common, local long-fruited variety, on inoculation, was the same as that of Black Beauty.

Holmes (13) has reported the systemic necrosis of seedlings of the Black Beauty variety when inoculated with the virus whilst very young, the resistance to systemic infection being found to increase rapidly with the age of the plants. Necrotic primary lesions on the inoculated leaves were found to precede this systemic infection. The difference in behaviour of the Black Beauty variety, when inoculated with *Nicotiana Virus* 1 in Trinidad and U.S.A., may be due to a slight difference in the virus or in the variety itself, or it may be due to the different environmental conditions prevailing in the two countries. A faint mottling of the younger leaves is often noticeable on mature egg-plants on the College farm, but the sap of such plants produced no symptoms when rubbed over the leaves of tomato or tobacco seedlings. The mottling may be due to mites, which are common on the under surfaces of the young leaves.

VII. Agricultural Importance of Tobacco Mosaic

The infection of a crop of tobacco with *Nicotiana Virus* 1 may cause losses due to breaking and crumbling of the leaf during the curing process. In Trinidad there is little loss due to this cause, while the check to growth produced by the virus seems to be slight compared with the effects of waterlogging. The loss caused by mild mosaic of tomatoes is negligible. The virus has caused serious losses in crops of peppers, but these are only grown on a minor scale.

Considering its infectious nature, it is surprising to find that very few insects have been cited as vectors of the virus. Hoggan (10) has shown several aphid species to be capable of transmitting the infection from tomatoes and transmission by hawk-moth larvae and mealy bugs has been recorded. Smith (22) considers that the virus is not normally insect borne, or is only so transmitted with difficulty. He considers man to be the chief agent in its spread, pruning operations causing considerable transmission. Since the virus can persist in dead tissues, some infections may arise through contact with plant debris, but, as the virus is apparently incapable of infecting a plant through the roots, such infections will be few. There is little evidence that the disease can be transmitted by the pollen. Seed transmission of the virus may occur to a very slight extent when freshly extracted seed of tomato or tobacco is sown, probably due to the contamination of the outer surface of the seed with the highly infectious virus. The virus is said to retain its infectivity in cured cigarette or pipe tobacco, but chewing tobacco is much more likely to start infections. The slightest wounds, even damaged hairs, can allow the entry of the virus, and, since such wounds are always present, there can be no real proof of the suggestion that the virus can enter through the stomata.

Holmes (11) has reported that the virus can multiply in species of many plant families and he considers that all, or nearly all, Solanaceous plants can be infected, although, in some, the virus remains localised near to the site of inoculation. This suggests the importance of weeds and ornamental plants, particularly those belonging to the

Table III.—Inoculation experiments with Nicotiana Virus 1

Source of inoculum	Plants inoculated	Number inoculated	Number infected	Incubation period (days)
tobacco	tobacco	20	20	10 (approx)
,, ...	tomato	8	8	7- 9
,, ...	sweet pepper	18	18	4-12
,, ...	hot pepper	10	10	4- 7
,, ...	egg-plant (local)	7	7	3*
sweet pepper	sweet pepper	4	4	12
,, ,, ...	tobacco	10	10	5- 8
,, ,, ...	tomato	15	15	7-13
tomato	,, ...	10	9	8- 9
,, ...	tobacco	10	10	10-21
,, ...	egg-plant (Black Beauty) ...	20	20	2- 3*
bird pepper (*C. frutescens*) ...	tobacco	10	0	—
,, ,, ,, ...	tomato	11	0	—

* Primary symptoms only.

Note.—All control plants remained healthy, except for one tomato seedling which was probably accidentally contaminated.

Solanaceae, as reservoirs of infection. In Trinidad, mosaic mottling symptoms were found on *Solanum torvum* Sw. and *S. seaforthianum* Andr., but juice extracts of these plants produced no symptoms when rubbed on to the leaves of tomato or tobacco plants.

Most of the measures suggested for the control of this virus would be either impracticable or uneconomic for small scale conditions such as those obtaining at the College farm. Smith (22) recommends the removal of infected plants from the field prior to pruning, and the burning of suspiciously mottled plants in the seed beds, together with their immediate neighbours. He also considers inadvisable the use of tobacco trash for burning on seed beds or fertilising, and the use of seed from affected plants. The removal of weeds, especially those of the Solanaceae, from the vicinity of the seed beds is also advocated. Resistant varieties of tobacco exist, the Ambalema variety and other varieties also originating in Colombia being probably the most satisfactory. Holmes (12) considers resistance in peppers to be due to the localisation of the virus in an inoculated leaf or shoot, which is then abscissed, resulting in the loss of all the virus from the plant tissues. The gene governing this response is present in Tobasco pepper and its derivatives. Some varieties are said to show partial localisation, abscission being followed by the appearance of a faint mottling restricted to the youngest leaves.

VIII. Other Suspected Plant Viruses in Trinidad

In addition to those already mentioned, symptoms of a mosaic type have been observed affecting the following plants :—*Capraria biflora* Linn. (*Scrophulariaceae*) ; *Sphenoclea zeylanica* Gaertn. (*Campanulaceae*) ; *Alternanthera ficoidea* (Linn.) R. Br. (*Amaranthaceae*) ; *Ageratum conyzoides* Linn. (*Compositae*) and *Sida* spp., *Malachra alceifolia* Jacq. and *Hibiscus esculentus* Linn. (*Malvaceae*). A few of these have received some attention, although results have so far been largely negative, and it is hoped to continue work on some of them. The prevalence of mosaic symptoms on members of the *Malvaceae* is interesting ; the leaf mottling of *Gossypium* which has appeared in Trinidad and a mosaic which occurs on *Hibiscus abelmoschus* Linn., neither of which have been seen by the writer, should also be mentioned. Davis (6) showed a number of Malvaceous plants to be capable of infection, by grafting, with the Abutilon Infectious Variegation Virus (*Abutilon Virus* 1 K.M.S.), whilst a mosaic of *Hibiscus esculentus*, transmissible by grafting or by the vector, *Bemisia gossypiperda*, has been reported from India (1).

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NOTES ON THE NATIVE COTTONS OF TRINIDAD

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Two species of cotton have been long established in Trinidad, namely, Marie-galante, *G. hirsutum* L. var. *marie-galante* (Chev.), Hutchinson, and free and kidney-seeded forms of *G. barbadense* and *G. barbadense* L. var. *braziliense* (Macf.) Hutchinson.* According to Williams and Cheesman (1929), Marie-galante is "perhaps native, but of ancient cultivation and possibly naturalised in Trinidad and Tobago". They recorded it from "coastal banks and waste grounds inland". Of kidney cotton (which was the only variety of *G. barbadense* that they considered), they stated that it is "probably naturalised" and is "cultivated; sometimes spontaneous in waste grounds".

Since it has been shown (Hutchinson, 1943) that, in Jamaica, Marie-galante cotton is frequent in the dry zone whereas *G. barbadense* is confined to more mesophytic situations, it seemed worth while collecting quantitative data on the distribution of the two types in different ecological areas of Trinidad. It was decided to take samples on a route running along the Eastern Main Road from St. Augustine to Sangre Grande, thence by the Guaico-Tamana Road and connecting roads south to Four Roads, thence west to Longdenville and north to St. Augustine by the Southern Main Road. The rainfall in the area surveyed varies from about 100" east of Valencia and Four Roads to about 60" in the Southern Main Road section, and the ecological conditions from heavily wooded country with cacao and other orchards in the heavy rainfall areas to open sugar-cane country where the rainfall is lower. (*See* Note on Ecology, for which I am indebted to Prof. F. Hardy.)

From casual observation it appeared that Trinidad cottons are generally to be found in house-yards, and, in the belief that their occurrence elsewhere would not be sufficiently frequent to vitiate the data, counts were made of the number of house-yards by the roadside with and without cotton shrubs. A careful watch was maintained for cottons growing in open scrub on abandoned lands, and none was found beyond the limits of house-yards, or immediately adjacent land which had obviously been under cultivation when the plants were established. It may be inferred that, in the area surveyed, cotton seedlings only established themselves in places artificially cleared for cultivation. It was further noted that cottons never occurred in house-yards heavily shaded by trees, and it appears evident that shade is the primary factor in limiting their distribution.

The distribution and frequency of the two species are given in Fig. I, and the sample data in Table I. The approximate line of division between the cane belt to the west, and the orchard (cacao and citrus) belt to the east is indicated by the dotted line in Fig. I. The Arouca, Arima and Talparo-Todd's Road samples may be regarded as transitional between the cane and orchard belts. Arouca is a heavily shaded village, with mango, star apple, cedar, and other trees in most house-yards. The percentage of house-yards with cotton was consequently considerably lower than in neighbouring villages. No *barbadense* cottons were seen in either Arouca or Arima, so the relative frequency of the two species was that characteristic of the cane belt. Cane cultivation has been extended in recent years from Todd's Road towards Talparo, and it was noted that the frequency of cottons and the proportion of Marie-galante were both higher near Todd's Road than near Talparo. Omitting the three border-line samples, samples in each zone formed a homogeneous group, and gave in all:—

	Without cotton	With *marie-galante*	With *barbadense*	Total
Cane belt				
Total... ...	672	124½	10½	807
Percentage ...	83.3	15.4	1.3	100.0
Orchard belt				
Total... ...	308	14½	18½	341
Percentage ...	90.3	4.3	5.4	100.0

* For nomenclature, see Hutchinson (in press). *G. hirsutum* var. *marie-galante* = *G. purpurascens* Poir. the Bourbon cotton, and *G. barbadense* var. *braziliense* = *G. lapideum* Tussac, the kidney cotton of Williams and Cheesman (1929).

Table I

Trinidad Cotton Census 6.10.43.

Sample	*Number of houses with*								
		marie-galante			*barbadense*				
	No Cotton	*R*	*G*	*Total*	*R*	*G*	*Total*	*Grand Total*	% *M-G* B
Tunapuna Road-Maingot Road-Baltazar Street (Tunapuna) ...		6	3	-	—	1			12.5
									1.4
	62			9			1	72	13.9
Paradise, Tacarigua		$5\frac{1}{2}$	$8\frac{1}{2}$		—	2			18.2
									2.6
	61			14			2	77	20.8
Arouca		2	2		—	—			3.9
									—
	99			4			—	103	3.9
Arima		5	8		—	—			11.8
									—
	97			13			—	110	11.8
Valencia		—	5		1	6			5.6
									7.8
	78			5			7	90	13.4
Sangre Grande		3	1		—	2			5.1
									2.6
	72			4			2	78	7.7
Guaico-Cunaripo-Cumuto Road Junction		1	—		—	2			2.0
									3.9
	48			1			2	51	5.9
Cumuto Road Junction-Coryal ...		1	$1\frac{1}{2}$		1	$3\frac{1}{2}$			7.4
									13.2
	27			$2\frac{1}{2}$			$4\frac{1}{2}$	34	20.6
Coryal-Four Roads		—	—		—	1			—
									2.2
	45			—			1	46	2.2
Four Roads-Talparo		1	1		2	—			4.8
									4.8
	38			2			2	42	9.6
Talparo-Todd's Road		5	4		1	5			10.0
									6.7
	75			9			6	90	16.7
Todd's Road-Longdenville		6	5		—	2			19.3
									3.5
	44			11			2	57	22.8
Longdenville Station-Montrose Junction		1	$19\frac{1}{2}$		—	$1\frac{1}{2}$			14.8
									1.1
	117			$20\frac{1}{2}$			$1\frac{1}{2}$	139	15.9
Montrose Junction-Chin Chin Road Junction		10	18		—	3			16.6
									1.8
	138			28			3	169	18.4
Warren		4	12		—	1			11.7
									0.7
	120			16			1	137	12.4
Caroni		2	2		—	—			13.3
									—
	26			4			—	30	13.3
Tull		—	10		—	—			25.6
									—
	29			10			—	39	25.6
Curepe		5	7		—	—			13.8
									—
	75			12			—	87	13.8
Total		$57\frac{1}{2}$	$107\frac{1}{2}$		5	30			
	1251			165			35	1451	

Yards with plants falling in two classes were assigned half to each class.

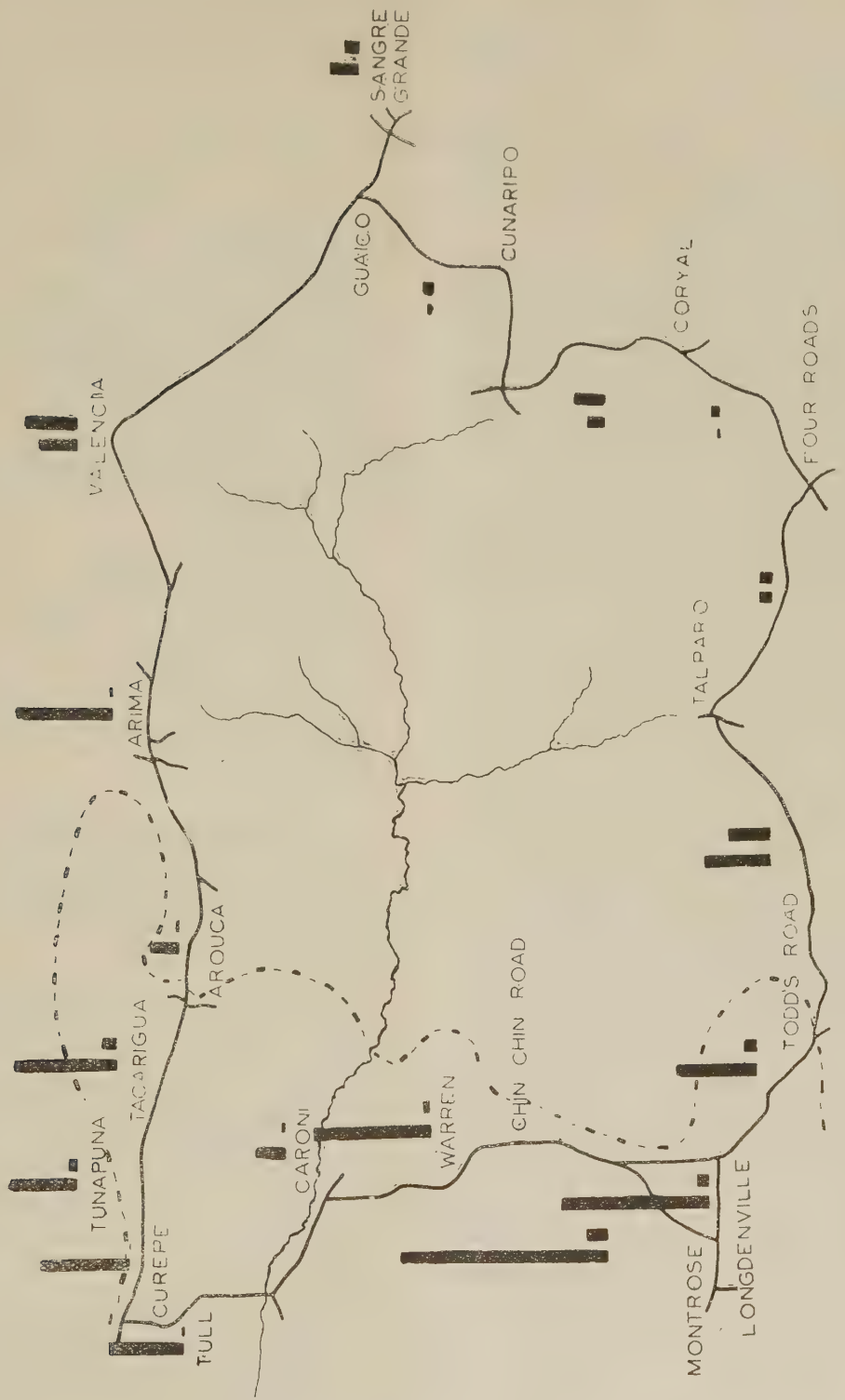
SANGRE GRANDE
GUAICO
CUNARIPO
CORYAL
FOUR ROADS
VALENCIA
ARIMA
TALPARO
AROUCA
TACARIGUA
TUNAPUNA
CUREPE
TULL
CARONI
WARREN
CHIN CHIN ROAD
TODD'S ROAD
MONTROSE
LONGDENVILLE

FIG. I.

The total frequency of cottons in the orchard belt was only about 60 per cent. of that in the cane belt. It was noted also that, whereas in the orchard belt it was unusual to see more than one cotton plant in a house-yard, in the cane belt they frequently occurred in small colonies of up to half-a-dozen plants. The distribution of the two species was even more distinct. Marie-galante occurred in 92 per cent. of the yards with cotton in the cane belt, and in only 44 per cent. in the orchard belt.

Some observations were made on the variability of the two populations. Red-leaved types occurred in both, and were easily scored. Red and green plants are recorded separately in Table I. Red was much commoner in Marie-galante than in *barbadense*, and in Marie-galante it was much commoner in the northern part of the area sampled than in the south. No reason can be given for this difference.

In the Marie-galante population, two leaf shapes were observed, closely similar to those which Stephens (*in press*) has shown result from the action of the alleles 1 and L^E on a Marie-galante genotype. The lacinated leaf (L^0) type, common in Jamaica, was not recorded. It has been collected in Trinidad (the Cassava type used by Stephens (*in press*)), but it is evidently rare. No obvious differences in habit were seen, and no Marie-galante plants were flowering at the time (early October) when the counts were made. Among the *barbadense* cottons, even less variability was observed. A few plants had just begun to flower, and all flowers seen were pale cream. The difference between the free-seeded, typical *G. barbadense* and the very large leaved predominantly kidney-seeded, *G. barbadense* var. *braziliense*, could usually be observed, but it was not sufficiently marked to be recorded in a rapid census in which only those plants were counted that could be seen from the road.

Discussion.—Young cotton shoots are used to make an infusion which is given to children as a vermifuge, and the lint is sometimes used for stuffing pillows and mattresses. Among the East Indians it provides wicks for lamps used for ceremonial purposes, but it does not appear to be particularly favoured on this account, as there is no evidence that it is commoner in East Indian than in negro house-yards in the orchard belt. It is frequently planted, and where it comes up from scattered seed, it is very often encouraged and protected. Its complete absence from all kinds of clearings other than house-yards, and from scrub land, is good evidence that it is not indigenous in any part of the area sampled; but for the encouragement it receives, it would therefore rapidly die out. *G. barbadense* in particular, which is evidently best suited to clearings in the orchard belt, would very rapidly be extinguished by the closing of the forest canopy if human interference were to cease. Marie-galante cottons, on the other hand, are found on the comparatively dry western coasts and islands of Trinidad, and the possibility that they may be indigenous there cannot be ruled out. I am indebted to Dr. Callan for seed of a Marie-galante cotton with very inferior lint, a small colony of which he found growing on an open exposed hillside, about 150′ above sea level, on Patos, a very dry island covered with xerophytic scrub, lying between Trinidad and Venezuela. Since there is one house on Patos, the possibility that it was introduced by human agency cannot be ruled out, but, however it reached the island, it had become established in a situation where it owed nothing to man.

Whether or not Marie-galante cotton is indigenous in small areas, its position in Trinidad is very different from the one it occupies in drier countries such as southern Jamaica, where it is not confined to house-yards, but also occurs as scattered individuals or small colonies in xerophytic scrub land far beyond the present limits of cultivation, and where the variability in vegetative characters is considerably greater than in Trinidad.

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Note on Ecology and Soils

The vegetation of areas *west* of the dotted line in Fig. I is an "open" type consisting of sugar-cane with some rice in small low-lying areas, and cleared savanna, comprising a large aerodrome south of Arouca.

The vegetation *east* of the dotted line is mainly "closed", consisting of the following chief types, in order of abundance:—

(1) Second-growth high bush ("lastro"), mostly under peasants' shifting cultivations.
(2) Reserved forest and Crown land forest (Evergreen Seasonal Forest).
(3) Orchard Savanna (north of the Caroni River).
(4) Cacao (lining the banks or "vegas" of the Caroni River and its main tributaries).
(5) Citrus (mostly in two fair-sized estates).
(6) Rice (in small plots in the wet hollows).
(7) Village areas and pastures.

The *soils* comprising the sugar-cane lands are mostly well-drained sandy-loams (except in the rice flats), and sand over clay in the aerodrome area. The soils of the bush or forest lands *east* of the dotted line comprise a "catena" made up of sandy hill-crest soils alternating with bottom-land clays, the whole having regularly-undulating relief. The soil of the orchard-bush savannas comprises sand over clay, and that of the cacao lands, fine silty-clay; these soils exhibit drainage impedance and general hygrophytic conditions during the greater part of the year.

WITCHES' BROOM DISEASE INVESTIGATIONS

VII. Observations on Direct Control

BY

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Introduction

The possibility of direct control of Witches' Broom disease (*Marasmius perniciosus*) of cacao on an estate scale has been considered previously (1). Experiments were described in which brooms were removed from trees once or twice a year on areas of between 25 and 80 acres, surrounded by cacao trees from which no brooms were removed. Effective control of the disease was not obtained under the conditions of these experiments. Concurrently with those investigations, a plot experiment was undertaken at Marper Estate, to compare the relative effects on neighbouring plots, of no removal of brooms with their removal at monthly intervals. The results of this experiment are given below but they cover vegetative and cushion brooms only. It was not possible to consider the occurrence of pod infection as a part of this experiment because many of the trees had not reached the stage of bearing when the experiment ended. It is of interest in this connection, to record earlier information which relates to percentages of pod infection within estate cacao fields bounded by neglected properties where little or no removal of brooms was untaken. Crop records made at Non Pareil Estate were generously placed at the disposal of the Department of Agriculture by Mr. E. A. Robinson through whose kind permission the results from an examination of these records are now published for the first time.

Small-scale Experiment on Direct Control

This experiment was undertaken to observe whether there were differences between numbers of brooms produced in plots where the brooms were not removed from the trees as compared with plots where the brooms were removed from the trees every month during a period of two and a half years. It might have been expected that the spores discharged from sporophores (mushrooms) produced on brooms which were allowed to remain on the trees would cause some infection in the vicinity and thereby possibly lead to a greater number of brooms being produced in the plots where brooms were allowed to remain, as compared with those plots where the brooms were removed every month. There should have been no opportunity for spores to be produced within the plots where the brooms were removed every month, because sporophores are never produced on green brooms. Baker and Crowdy (2) found the minimum period of time between broom formation and sporophore production to be ten weeks. Therefore, no spores would have been produced within the plots where the brooms never remained on the trees for longer than four weeks. All the plots in this experiment were equally exposed to the possibility of infection by air-borne spores formed elsewhere, but the plots where the brooms were not removed from the trees were likely to receive additional spores from sporophores produced within these plots. Thus it might have been expected that more brooms would in consequence be formed on such plots compared with the others where brooms were removed.

There was a possibility that the cutting of the trees in the course of the routine procedure of removing brooms might have an effect on broom production, in contrast to the trees which received no such cutting. It was suggested by Briton-Jones and Cheesman (3) that pruning might possibly increase broom formation, under certain conditions, since the process of cutting might enhance the production of young shoots which were liable to infection. It was possible, therefore, that the removal of brooms at monthly intervals might also stimulate the production of young shoots, some of which might become infected, thereby adversely affecting the attempt at direct control by the cutting of brooms.

It was desirable, for the purposes of this experiment, that the treatments should be carried out on small trees which could be readily searched for brooms. A suitable block of cacao was available at Marper Estate, which is in the locality where witches' broom disease has been prevalent since 1928. The trees used were the progenies of trees selected locally for possible resistance to witches' broom disease. Preliminary observations had shown that although the general incidence of brooms in this block was low, none of the selections was entirely free from brooms. Although it would have been advantageous to have been able to carry out the experiment on trees with a higher general incidence of witches' broom disease, this disability was largely outweighed by the small size and regular spacing of the trees, which facilitated the observations. This cacao was planted in 1937 and 1938, at a closer spacing than is usual (6′ × 6′).

There were six blocks, each of which consisted of 144 trees of one budded clone or of the same number of seedling progeny from one individual tree. Each block was divided into two equal plots of 72 trees. In one such half of each block, the brooms were removed once every month, and in the other half, the brooms were allowed to remain on the trees. The recording of brooms was done on plots of six trees, situated in the centre of each half-block. These plots of six trees were thus completely surrounded by three guard-rows which received the same treatment as the six trees they surrounded.

For the purpose of recognizing the new brooms in the plots where none was removed, the brooms were labelled when recorded for the first time, so that only those brooms produced after the previous recording were noted on each occasion, vegetative and cushion brooms being recorded separately. Observations were also made on the first appearance of sporophores and also on the length of time the brooms remained before falling naturally. The results of such observations were in general accordance with those reported previously (4).

Results

The results of this experiment are summarized in Table 1, in which the numbers of vegetative and cushion brooms are combined. It will be seen that more brooms were formed on the trees from which brooms were periodically removed (488 brooms), as compared with those plots where the brooms were allowed to remain on the trees (440 brooms); these totals are equivalent to means of 3.4 and 3.1 brooms per tree respectively. Throughout the six blocks the difference was not consistently in favour of either treatment.

Table 1

Numbers of Brooms recorded for Plots of Six Trees each, during the Period 22/4/40 to 29/10/42

Blocks	Budded Trees			Seedling Trees			Total
	I	II	III	IV	V	VI	
Brooms removed ...	102	65	63	75	36	147	488
Brooms not removed ...	85	47	79	99	61	69	440
Total ...	187	112	142	174	97	216	928

Statistical analysis showed that the treatment effect was not significant, either for total brooms, as in Table 1, or when numbers of vegetative and cushion brooms were analysed separately.

It is considered therefore, that no importance can be attached to the small apparent difference between the two treatments, as regards control of witches' broom disease, nor is there any apparent support for the suggestion that frequent cutting might enhance broom production. In the experiments previously described (1), there was no effective control of witches' broom disease on areas of 25, 40 or 80 acres where brooms were removed once or twice in the year. It is now shown that no control of the disease was exercised by monthly removals of brooms from small plots, during a period of two and a half years.

Estate Observations on Pod Infection

Non Pareil Estate, near Sangre Grande, is situated in the high rainfall region of the east of Trinidad where witches' broom disease is generally severe. The estate records show considerable local variation in the intensity of the disease which sometimes appeared to be more severe where certain smaller properties adjoined the estate. It was usual to find that little or no removal of brooms was undertaken on such properties, in contrast to the routine work in the cacao fields of Non Pareil Estate. The estate records were accordingly studied in order to ascertain whether there was any evidence to support the view that neglected neighbouring fields might be dangerous sources of witches' broom disease and consequently detrimental to an estate where the removal of brooms was undertaken.

Yields of individual fields at Non Pareil Estate were recorded as 'wet cacao' and diseased pods. The former were converted to pounds of dry cacao, and thence to yields as numbers of pods, by multiplying by twelve. With the aid of such calculated numbers of pods produced in the

Table 2

Yields and Numbers of Diseased Pods for Certain Fields on Non Pareil Estate in 1940

Field	No. of trees	Total pods	Healthy pods (Calculated)	Diseased pods (Counted)	Diseased pods as percentage of total pods	Notes on Situation
					%	
1 ...	4124	48768	36828	11940	24.5	Surrounded by heavily diseased neighbours
2 ...	3915	53183	40986	12197	22.9	Heavily diseased neighbours on one side
3 ...	6568	162631	131274	31357	19.3	Mainly bounded by estate cacao
4 ...	3130	46327	37422	8905	19.2	Surrounded by estate cacao
5 ...	4923	99118	80784	18334	18.5	Heavily diseased neighbours on one side
6 ...	4212	102880	86130	16750	16.3	Mainly bounded by estate cacao
Total ...	26872	512907	413424	99483	19.4	

individual fields, the approximate percentages of diseased pods were determined and the results are given in Table 2. It will be seen from Table 2 that percentages of diseased pods ranged from 16.3% to 24.5% in the individual fields sampled. The mean percentage of diseased pods for the six fields combined was 19.4%, whilst the percentage of diseased pods for the whole estate in the same year (1940) was 19.2%. The situations of the fields sampled, ranged from a complete surround of neglected fields, where the estate percentage of diseased pods was 24.5%, to the condition where the sampled field was entirely surrounded by estate cacao, when the percentage of diseased pods was 19.2%. In the sampled fields which were not entirely surrounded by neglected cacao, the percentages of diseased pods ranged from 16.3% to 22.9%.

Amongst the six fields studied, the highest percentage of diseased pods (24.5%) was that of an estate field which was entirely surrounded by neglected properties. On the other hand, the estate field with no neglected fields adjacent to it had a percentage of diseased pods (19.2%) which was greater than that of either of two estate fields partially bounded by neglected ones (16.3% and 18.5%).

It appears from these figures that estate fields which were bounded by neglected properties did not invariably have percentages of infected pods which were greater than those of fields surrounded by other estate fields. This result agrees with that from experiments previously described (1) where it was found that pod infection was not consistently different where brooms were allowed to remain on the trees as compared with areas of 25, 40 or 80 acres where the brooms were removed once or twice during the year.

Summary

1. A plot experiment is described which was designed to compare the effect of removing witches' broom affected material every month, with that of allowing such material to remain on the trees.

2. There was no significant difference, as regards the numbers of brooms formed, between the two treatments.

3. Estate figures of healthy and diseased pods have been examined with respect to the position of certain fields relative to other properties where the removal of brooms was generally neglected.

4. There did not appear to be any consistent effect from such neglected properties on the incidence within the estate of pods affected with witches' broom disease.

5. These observations are in agreement with the results from previous experiments where 'controlled' areas of 25, 40 or 80 acres were surrounded by trees from which no brooms were removed.

Acknowledgment

The writer is indebted to Mr. R. E. D. Baker for his examination of the data from Non Pareil Estate and also for advice in the preparation of this paper.

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THE DRYING OF FARM CROPS*

Most farmers are familiar with Dr. Woodman's work at Cambridge on the drying of young grass and it is not necessary here to emphasize the distinction between grass drying and hay drying. Dried grass correctly produced provides a home-grown feeding stuff equal in nutritive value to concentrated foods manufactured from imported materials and in addition contains vitamin-A or carotene in proportions almost equal to that of the fresh material. Grass drying is very dependent on the cultivation and management of the land producing the fresh material, and properly controlled land will yield up to 3 tons per acre of dried young grass containing about 10 cwt. of crude protein, which is nearly five times as much crude protein as would be produced from the same crop taken as hay, and 1 lb. of first quality dried grass is equivalent to 1 lb. of concentrate. Farmers who have fed dried grass are well satisfied with the results and fully confirm the laboratory work, but in spite of this, grass drying has not progressed as much as was hoped or expected.

One of the main disappointments has been that the dried material produced on farms is a good deal lower in quality than the published figures from experimental work, and varies widely from sample to sample. If a product is to replace concentrates brought from outside it should be as consistent in analysis as the concentrates themselves so that it can be fed to full advantage. It is true that samples may be sent for analysis, but only a very detailed estimation is of any real assistance. For instance, the crude protein content does not always indicate the amount of the all-important digestible protein. Carotene and mineral content are also important and may have

* Abridged from an article by W. H. Cashmore published in *Chemistry and Industry*, Vol. 62, No. 30. 1943.

been destroyed in the drying process or have been deficient in the original material. The variation in the food value of the fresh material is the most frequent reason for divergent values in the final product. Even so-called good quality pastures vary widely in nutritive value and it is obvious that the value of dried grass cannot exceed that of the fresh material compared on a dry matter basis. Experiments have shown that the best results are obtained when a pasture is cut five or six times in the season. Such a procedure offers difficulties in collection and because the yield at each cut is comparatively low, the labour requirement per ton of dry material is too high. On the other hand, it is unsatisfactory to risk cutting the grass in a state where the nutritive value has appreciably deteriorated. It is suggested that more attention should be paid to special grasses and clovers grown in the arable rotation. Given the necessary dressing of fertilizers and good general management, a consistent high quality material would be available for drying and the crop would not reach maturity so rapidly as the average pasture, and should yield a heavy crop twice a year and still be in the young grass state when cut. A crop cut two or three times for dried grass removes three or four times as much nitrogen, potash and phosphate as a hay crop and fertility cannot be maintained without a high application of fertilizer. A certain amount of damage after drying has taken place through faulty storage. Dried grass must be kept dry and be protected from sunlight. The most satisfactory form for storage is in high density bales or as meal.

The cost of production is the other main factor which has retarded development. The value of dried grass on the farm depends on the ruling price of the concentrate it replaces. Even allowing for the amount of medium quality material produced there has been a margin of profit since driers passed the early experimental stage, but generally, this margin has not been sufficiently great to make the new industry worth the risk to the average farmer. Without doubt costs of production can be considerably reduced, not by sensational developments in the design of driers, but rather by all round improvements in farming methods and equipment.

The pre-war price of a drier capable of producing from 2 - 3½ cwt. of dry material an hour was £450 - £650. To this must be added the cost of foundations, shed, baling press, etc. Only if grass drying became popular enough to allow mass production could the cost be appreciably reduced.

The General Principles of Grass Drying

The moisture content of the fresh material varies from 70 per cent. to nearly 90 per cent. depending on the rainfall over the growing season, and the presence or not of external moisture. The final product should contain not more than 10 per cent. moisture. The difference between the average moisture content of the fresh material in a wet and dry season is 4 per cent. or 5 per cent. A heavy dew makes as much difference as ½ in. of rain and for this reason farm driers as distinguished from factory driers should only operate on material collected free from rain or dew. The ratio of fresh material to dry material is: $(100-A)$ to $(100-B)$ where A is the final moisture and B is the initial moisture. The tons of water to be evaporated to leave 1 ton of dry material is $\frac{(100-A)}{(100-B)}-1$. This is called the water ratio.

Drying down to 10 per cent. moisture the water ratio is 5.0 with 85 per cent. initial moisture, 3.5 with 80 per cent. and 2.6 with 75 per cent. Thus a drier operating on material of 75 per cent. moisture will have a throughput nearly twice that of material of 85 per cent moisture. To have an output of 2 to 3 cwt. of dry material a farm drier must evaporate 5.0 to 7.5 cwt. of water per hour. Although this may appear to be a low rate of working, appreciably higher rates cannot be expected without much more expensive plants and these could not be justified unless operated on a factory scale.

The moisture in the material going to the drier can be reduced by leaving the crop in the field for a time before collecting, but the expediency of allowing grass to wilt even for a few hours in favourable weather is a controversial point. The advantages are obvious: carting costs are reduced and the throughput of the drier is increased. Unfortunately the carotene in the herbage falls fairly rapidly during wilting because of the exposure to sunlight, and respiration lowers the digestibility. In addition there is the difficulty of picking up a wilted swath without loss. On balance it seems that the herbage should be collected in a fresh state if high feeding value and good organization are to be maintained. A small grass drier requires 4 to 5 tons of fresh material for 8 hours drying and a meduim-sized one 6 to 8 tons. If this is cut and collected between 11 a.m. and 5 p.m. during the day when the dew is off, it contains up to 5 per cent. less moisture and the throughput will be increased by something up to 30 per cent. This, of course, is not practicable for a drier operating on a factory scale. To reduce the cost of cutting and collecting, fresh material will generally be in a fairly long state. In this form it is inclined to be unequal in texture. It forms rolls in rotary driers and needs tedding when on tray or conveyor driers. To overcome this, chaffing into short lengths is strongly recommended. The only disadvantage of chaffing is that it is impossible to bale the dry material and the only satisfactory method of handling it is to grind in a hammer mill and store in sacks. The expense of a hammer mill is not justified with a small plant.

A satisfactory grass drier should remove water efficiently from freshly cut grass without changing the nutritive value of the grass, and at a rate satisfatory for the requirements of the farm. It has been found that the most suitable method of drying grass is by passing a current of hot air through the material. The hot air supplies the

heat necessary for the evaporation of moisture and also carries off moisture in the form of vapour. The total heat in the ingoing air equals the total heat leaving in the discharge air, together with the heat losses from the drier itself and the heat remaining in the dried material. Because of the latent heat of water vapour the discharge air is at a lower temperature than the ingoing air. For high thermal efficiency the exit air should be fully saturated and the higher the saturated discharge temperature the greater is the proportion of heat in the water vapour to the heat in the air itself, and consequently the higher the thermal efficiency. High exit saturation temperatures can be obtained by employing high inlet temperatures, provided they are not high enough to damage the material. Grass does not suffer from case hardening and initial temperatures of 1000°F. have been used without harmful effects, because the rapid evaporation keeps the material below the critical point. Dry material is more susceptible to heat than the wet grass and air temperatures through the dry material should not exceed 300°F. if carotene and digestibility are to be unharmed. It is difficult to obtain a saturated discharge when using high air temperatures. An alternative method of raising the exit saturation temperature is by causing the air to pass through the material in two or more stages, and reheating between the stages.

Switzerland has recently seen the development of high thermal efficiency drying by the Brown Boveri Company. A reduction in the heat units required to evaporate a given amount of water is obtained by employing a special "heat recuperation" method which recovers part of the heat contained in the water vapour leaving the first stage and uses it to help heat the air for the second stage. Cheap electrical power obtained from water power is used for heating the air and, at the thermal efficiency obtained, the process is economical and helps in the conservation of fuel which are very scarce in Switzerland. Cheap farm driers have to work at air temperatures of about 300°F. and usually about 2000 B.Th.U. are required to evaporate 1 lb. of water. This is equivalent to an evaporation of 6 lb. of water per lb. fuel. By using the two-stage heating and reheating between the stages, an evaporation of 8 ½lb. per lb. fuel is obtained. This is typical of large farm driers and factory scale conveyor driers. The Brown Boveri heat recuperation method requires about 1150 B.Th.U. per lb. of water, which is equivalent to an evaporation of just over 10 lb. of water per lb. of fuel. The choice of a drier depends on whether it will be operated on a factory or farm scale. A grass drier with high thermal efficiency is more expensive and to justify this expenditure must be operated for long continuous runs. Generally, working in shifts is not popular on farms, and grass driers are often operated over convenient periods of the day only. Intermittent and short runs tend to give a low thermal efficiency and for this work the simple farm drier of comparatively low initial outlay is recommended. When the production of high quality material is aimed at, it seems necessary to have a competent supervisor in attendance and to justify this the output must be at least 5 cwt. an hour. The cost of such driers is likely to be £2000 upwards. Drying in stages, with recirculation and reheating, or heat recovery is then desirable. The main difficulty met with in such driers is the transport of material and the arrangements for a regular supply.

Classes of Driers

Driers may be divided into two main classes according to the way the grass travels relative to the hot air. (1) Counter-current driers in which the hot air leaves at the end where the grass enters, examples of this type are conveyor or tray driers. To avoid overheating the dry material, these driers work at comparatively low temperatures. (2) Co-current driers where the air enters at the wet end and leaves at the discharge end. Examples are rotary and pneumatic driers. High temperatures may be used without harming the material because the rapid evaporation cools down the air before it reaches the dry material. The air has less capacity for drying at the dry end and some difficulty is met with in obtaining the final moisture content required. Complete saturation at the discharge is not practicable. The use of high temperatures requires extra lagging to prevent heat losses which tend to counteract the advantages gained.

The types of British Farm Driers may be divided into the following four classes: (*a*) tray driers, (*b*) endless-belt driers, (*c*) rotary driers, (*d*) pneumatic driers. (*a*) In a tray drier, drying is on the batch system, usually in two stages. At the end of the first stage the half dried material is hand-tedded and moved into the second stage. It is a counter-current drier, the air passing first through the dry stage and then through the secondary stage, and is saturated before leaving. Initial air temperatures of about 300°F. are used and the material takes from 30 to 60 minutes to pass through both stages. The main disadvantage of this type of drier is the labour required for hand tedding, but, because it has a low initial price, the overall cost of drying compares favourably with other types.

(*b*) In the endless-belt drier, the fresh material is fed in at one end and, without handling, is discharged dry at the other end. Drying is in two stages, with reheating between the stages. Temperatures employed are about 300°F. under the wet end and 220°F. under the dry stages. In some types of conveyor driers a mechanical tedding device is fitted; others have alternate stages with air passing in different directions, and some employ a series of conveyors which cause the mat to cascade from one stage to another, and so mix up the material.

(*c*) In rotary driers the grass is dried in a slowly rotating drum, in which the material passes in the same direction as the air and is constantly agitated by the drum movement. The drier portions pass through quicker than the wetter parts and this prevents damage through overheating, but a steady feed is necessary to prevent the hot gases getting to the dry material before they are sufficiently cooled. Being a co-current drier, high initial temperatures are used. As has already been mentioned, some difficulty is experienced in getting the necessary final degree of dryness. Long material is apt to mat together and more satisfactory results are obtained if it is first chopped into short lengths.

(*d*) In pneumatic driers, the grass is first chaffed and then sucked through ducting in contact with furnace gases as high as 1200°F. The drying period is relatively short. In one type the wet and dry materials are separated by centrifugal force after one circuit; the dry is taken out and the wet grass crushed and recirculated. This type is suitable for drying such material as kale and beet tops.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Effects of Green Manures on Soils

Modifications in the properties of a soil when different green manures are added have been investigated and are reported in the 1941 *Ann. Rept.* of the Tea Research Institute, Ceylon. The essential fact has emerged that green manuring does not tend to acidify a soil, but rather to increase its basicity. Study of the water stability of soil has shown that tropical soils of quite different types are remarkably stable—much more so than temperate soils.

* * *

Vitamin-C Content of Tomatoes

An account is given in the *Annual Report* for 1942 of the Cawthron Institute, Nelson, New Zealand, of experiments designed to secure data concerning the Vitamin-C content of Nelson tomatoes. Several varieties were grown on typical Nelson soil, and also on another soil type at Wakatu. Much preliminary work was necessary to establish a technique of analysis which gave consistent results with representative samples of tomatoes. After numerous trials it was found that 20 tomatoes were necessary in each sample to secure an average Vitamin-C figure which was representative of the variety. The test showed that individual tomatoes on the same bunch varied considerably in their content of Vitamin-C, and that tomatoes from plants particularly exposed to sunshine were higher in Vitamin-C content than those from more shaded plants. Vitamin-C was found in the skin, the seeds and in the pulp, the latter containing about 70 per cent. of the total Vitamin-C of the tomato.

The following varieties were tested: Kondine, Sunrise, Kidson, Exhibition, Blakeley, Vetomold, Jan Ru, San Mazano, Tatura and Christchurch Special. The range in Vitamin-C content over three bunches of fruit on the above varieties was from 22.7 to 31.7 mgm. per 100 grams of fruit. Kondine, Sunrise, and Invincible varieties, followed closely by Exhibition and Blakeley gave the highest Vitamin-C content. Bonny Best, Kidson and Tatura gave the lowest figure. The tomatoes grown on the orchard soil at Wakatu were rather lower in Vitamin-C than those grown on Nelson soil.

* * *

Rapid Determination of Soluble Nutrients in Soil and Plant Extracts

B. Wolf, in *Industrial Engineering Chemistry* Vol. 15 (1943), No. 4, describes a method of establishing a correlation between crop yields and the amount of plant nutrients contained in the soil, by the use of a photo-electric colorimeter for measuring the exact shade of colour produced by adding indicators to soil extracts. For instance, the soil sample is extracted with the well known Morgan universal extracting solution. Instead of a mere visual comparison of colours or turbidities, which can only differentiate between certain levels of nutrients such as high, low or medium, the coloured or turbid solution is placed in the photometer cell, and the concentration of the nutrient in parts per million is read from previously prepared deflection-concentration curves or charts. By this method the result is expressed in definite figures instead of vague estimates. The concentration of nutrients in fresh plant tissues is determined by extracting them with the same universal extracting solution, and examining the extract in the photometric colorimeter. This affords a means of correlating the composition of the plants with the composition of the soil.

* * *

Soil Cultivation and Maize Production

Results of a mulching and cultivation experiment with maize during two seasons of contrasted rainfall are given in *Farm. S. Africa*, 17, 1942 (721-726). Weeds and drought have an identical effect on the growth of maize and other crops. The production of maize may be considerably increased by practising more effective weed control without extending the cultivated area. Generally, under dry-land production the numbers and times of cultivation should be determined by the appearance of weeds. The maintenance of a mulch appears to be unnecessary.